DETECTION OF DEFECT ON FBGA SOLDER BALLS USING X-RAY TECHNOLOGY

Pavel Řihák

Doctoral Degree Programme (2), FEEC BUT

E-mail: xrihak02@stud.feec.vutbr.cz

Supervised by: Ivan Szendiuch

E-mail: szend@feec.vutbr.cz

Abstract: The paper deals with the detection of defects using X-ray technology. It is focused on a particular type of X-ray machine, which is used for most of these experiments. X-ray cabinet is commonly used for analyzes of defects, which are formed during soldering process. Paper also includes an introduction of different types of defects. These defects are serious issue and they can cause malfunction of infected components or of the entire device. That is the main reason it is so important to focus on this issue.

1. INTRODUCTION

Defects may affect the quality of the solder joints after reflow process and it can lead to components malfunction. This is the main reason for the requirement of the complete defects analyses. There are known several methods for detection of defects.

Visual control is a most common used method for detection of defects. Visual inspection is made throughout all soldering processes and it allows monitoring created changes the whole time of the replacement process.

Microscope camera can be used for detection of defects as well, but we only can observe the surface of the device. Internal structure of affected components cannot be seen. Microscope camera is especially suitable for observation of mechanical damages. It is non-destructive and cheap (depends on the type of used microscope camera) method.

Micro-sections are destructive method, which is used for detection of defects. The printed circuit board (PCB) and the surface-mount device (SMD) have to be cut in the area which we want to observe. That means the PCB and the SMD are always irreversibly destroyed.

X-rays technologies are also used for detection of defects. It is non-destruction method, which permits checking internal structure. The biggest advantage is easy and fast inspection of soldered components. The main disadvantage is a high price of the X-ray machine.

The correct combination of these methods provides improvement of results and leads to elimination of defects during soldering process. The results are used for changing preparation of soldering and the actual soldering process.

2. MACHINE OVERVIEW

X-ray machine can recognize plenty of different defects, which are created during soldering process. X-ray technology is used as non-destructive method for optical detection of internal component structure. It is possible to observe the connections between component and PCB. X-rays can also examine the quality of PCB, especially when the multilayer PCBs are used. All surface-mount devices (SMD) can be observed using X-ray cabinet. It is particularly suitable for high components density of PCB.

Various types of X-ray equipments exist. We are using X-ray machine Nordson DAGE XD7600NT Ruby FP (Figure 1.). This equipment has been designed for inspection and determination quality of electronic devices. Because X-rays are harmful to the human body, this equipment was design to minimize escape of dangerous radiation. The machine is lined with lead or lead glass in all areas for shielding radiation. The thickness of the lead depends on expected level of radiation; the lead lining is thicker at the top of the cabinet. The machine requires regular semiannual measurement of radiation. The X-ray cabinet is internally divided into three sections.

- The radiation chamber contains X-ray tube and image intensifier for producing X-ray images. This chamber also contains a sample manipulator for positioning inspected samples.
- The electronic tunnel for housing most of the main electronic modules. The tunnel is completely shielded from X-rays generated in the radiation chamber.
- The computer tunnel for placing the control computer.

The power controls are placed on the main front panel; other controls are performed through a dedicated software application.

Figure 1: X-ray Cabinet Nordson DAGE XD7600NT Ruby FP

3. COMMON DEFECTS

A large proportion of defects are developing in ball grid array packages (BGA). Pitch of the BGAs become smaller and the ball size is reduced, the number of defects in individual ball becomes more of a concern. Using FBGA (Fine Pitch Ball Grid Array) is common now. FBGA are smaller and lighter than classic BGA that brings more issues even with small defects. That is the main reason why this part of the paper describes predominantly defects in FBGA solder balls. Defects can be caused by inappropriate temperature profile, improper PCB and BGA design, and derogation of technological processes or storing.

3.1. VOIDS

Voids are most common defects in BGA solder balls, they are formed because solder ball contains a flux, air or another kind of impurities. Voids can be caused by insufficiently long time under liquid temperature during temperature reflow profile; another reason can include excessive quantity of flux. Six types of voids in solder joints have been described (Figure 2.).

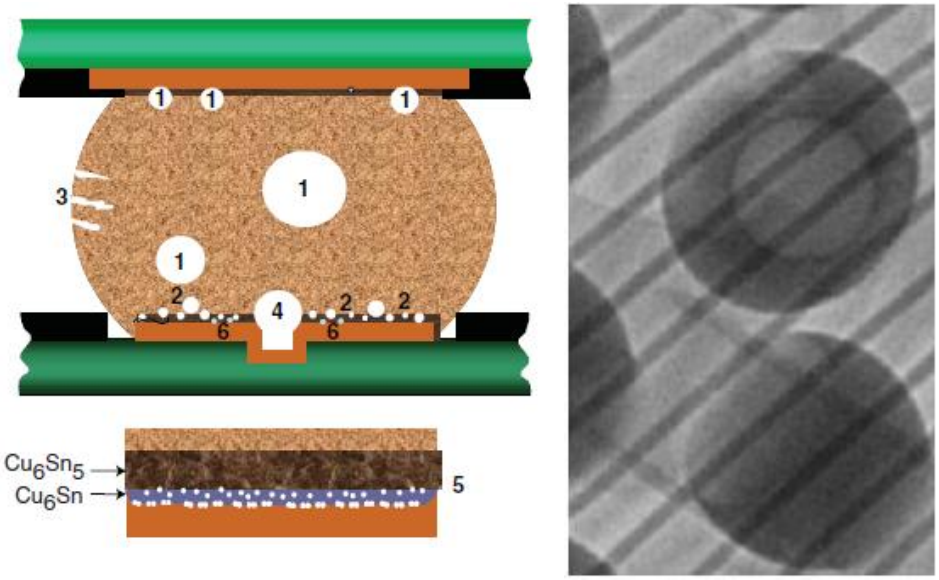

Figure 2: FBGA Solder Joint after Reflow Soldering and Macrovoid

1. Macrovoids – are most widely occurring voids in solder balls.
   – are caused by volatile compounds (flux) that evolve during solder process.
   – do not affect reliability of solder joints unless they are present at interfacial area in solder joint where cracks typically propagate.

2. Planar Microvoids – are located between the PCB and the solder.
   – are caused by copper caves under ImAg surface finish.
   – do not effect initial product quality, but they can affect long term reliability.

3. Shrinkage Voids – are caused by shrinkage during solidification.
   – are created in SAC or other lead-free solder.
   – can be minimized by increasing the cooling rate during soldering.

4. Microvia Voids – are caused by presence of micro-vias design in PCB.
   – platting micro-via or filling it by double printing can minimize their creation

5. IMC Microvoids – occur within Intermetallic Compound.

   – are formed between copper and high tin solder.

   – can affect reliability of solder joints.

6. Pinhole Voids – with sufficient quantity can affect reliability of solder joints.

   – are caused by entrapped PCB fabrication chemicals within these pinholes that volatilize during the reflow soldering process

3.2. OPEN JOINTS

Solder balls do not reflow parallel to the board surface leaving the terminations suspended above the pad surface. They are very clearly seen compared to the good joints under device. This defect can cause intermittent problem as working when the FBGA package is pressed down by finger, downward pressure can allows contact between the ball and the pad making an electrical connection but not a reflowed joint.

Can be caused by:

- Insufficient time about liquid temperature during reflow.
- Insufficient reflow temperature for melting the solder paste
- Lack of flux during rework process.
- Too small solder balls select for re-balling process.

Figure 3: Open joints

3.3. SOLDER SHORTS

Solder shorts are easy to detect during X-ray inspection, after reflow process is seen a large amount of solder present between the FBGA balls. They are caused by using too much solder paste or flux in the area array or PCB. Shorts are more likely after rework caused by debris on the PCB.

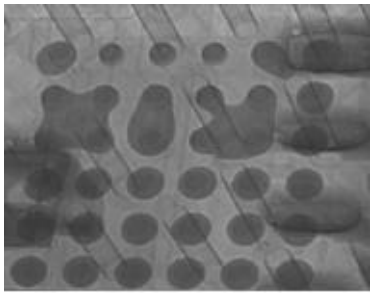

Figure 4: Solder shorts

3.4. DEFORMATION

Deformation of solder balls can be formed in case of temporary deformation of the substrate. The reason for this phenomenon may be different coefficient of thermal expansion, due to various substrate materials of the package and the PCB. This phenomenon is called dynamic deformation. Another reason why the solder joints are deformed can be their movement during the soldering process.

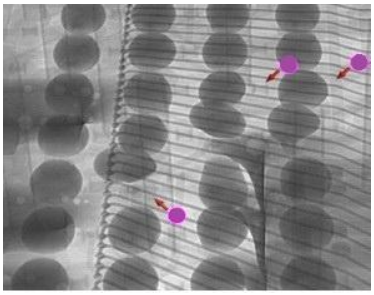

Figure 5: Deformation

4. CONCLUSION

This paper deals with using X-ray after soldering process. The main reason for using X-ray technology is detection of defects in the internal structure of joints, which lead to the interruption of the electric signal. It can help with detection of non-functional components. Simultaneously with an electric test or any other tests can improve correct functionality of soldering process. It also may help with the correcting deficiency of soldering process. Another advantage is that X-ray is a fast and non-destructive method.

ACKNOWLEDGEMENT

Funding for this research work is supported through grant project of the Czech Ministry of Education for Brno University of Technology FEKT-S-14-2168 "Research of modern and innovative technologies for packaging and interconnection in microelectronics". This work is created with support of the Sanmina-SCI Corporation.

REFERENCES

[1] Bernard D., "A Practical Guide to X-ray Inspection Criteria & Common Defect Analysis", Dage Publications 2006.

[2] IPC-7095C. Desing and Assembly Process Implamentation for BGAs. IPC, January 2013.

[3] LAU, John H. *Ball grid array technology*. New York: McGraw-Hill Professional, 1994, 635 p. ISBN 00-703-6608-X.

[4] SZENDIUCH, Ivan. *Základy technologie mikroelektronických obvodů a systémů*. Vyd. 1. Brno: VUTIUM, 2006, 379 s. ISBN 80-214-3292-6.